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The Testing of Timepieces...

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DEPARTMENT OF THE INTERIOR, CANADA

TOPOGRAPHICAL SURVEYS BRANCH

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BULLETIN No. 43.

THE
TESTING OF TIMEPIECES AT
THE LABORATORY OF
THE DOMINION LANDS SURVEYS



OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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INTRODUCTORY NOTE

The results of many branches of scientific and commercial work are dependent, to a large extent, on the accuracy with which time can be measured with the aid of watches. Watches, as well as all other precise measuring instruments, should be carefully tested before the results obtained with them can be relied upon. To meet this need, and to constitute independent testing authorities, national laboratories or bureaux have been established in several of the leading commercial countries of the world. Watches were among the first instruments to be tested at these laboratories. The advantage of certificates issued by such disinterested authorities is at once evident, both to the manufacturers and to the users of their products. It is customary among certain governments and large industrial corporations to purchase such articles as watches only on condition that they will pass the test of a recognized testing laboratory. In many instances the price paid for a successful watch is increased in proportion to the marks it receives as a result of the test. The large percentage of high grade watches that fail to reach the requisite standard clearly demonstrates the desirability of submitting them for independent trial before purchase.

THE TESTING OF WATCHES

It would be of great advantage if, where practicable, a universal standard were adopted by all engaged in the testing of manufactured products. With this end in view, and also because American made watches are common in Canada, the Surveys Laboratory has taken, as the standard for watch tests, the test programme and tolerances of the United States Bureau of Standards, the recognized testing authority in the United States. By this means no confusion is caused through the makers having to adjust their products to comply with two or more different standards. In practice the difference found between the methods of test at the various centres throughout the world is small, but it may be sufficient to cause uncertainty to those interested.

DEFINITIONS

Before describing the tests it may be well to define one or two terms employed in the description.

“Daily Rate”—The “daily rate” of a watch is the amount by which the time indicated by the watch in twenty-four hours differs from the true elapsed interval, or in the usual terms, the amount lost or gained in a day. The convention is adopted of calling the rate positive when the watch indicates less than the true interval, or loses; and negative when it indicates a larger amount of time than that elapsing, or gains.

“Isochronism Error.”—The daily rate is obtained by considering periods of twenty-four hours only. It is also necessary to know how the watch behaves during the intermediate interval. If a watch has a daily rate r , representing the amount gained or lost after the lapse of 24 hours from being wound, the corresponding increment gained or lost (according to the sign of the daily rate) after n hours from winding should be $\frac{n}{24} \times r$, e.g., after 8 hours from winding, the amount should be one-third of r . The amount by which the actual quantity observed differs from this is the “isochronism error” for the period considered. Generally, watches are adjusted so that the isochronism error is small during the first twenty-four hours, this being the usual period between successive windings.

“Temperature Compensation.”—Compensation for temperature is the attempt to make a watch run at as uniform a rate as possible under varying temperature conditions. In watches as ordinarily constructed, it is impossible to obtain perfect compensation for temperature, that is for the watch to have a uniform rate at all temperatures. The variation of rate with temperature usually follows a parabolic law of such form that the watch will have a given rate at two temperatures, while at some intermediate point, the rate is a maximum, both increase and decrease of temperature diminishing it. This temperature is known as the temperature of compensation and should be about the average temperature to which the watch will be exposed in use. In adjusting a watch the usual plan is for the adjuster to make the rates the same for the highest and lowest temperatures of the range over which the adjustment is extended, this being about all that can be accomplished, with a movement of the usual type.

METHOD OF TESTING

The watches, during the trial, are kept in well insulated chambers, the temperature being automatically regulated by means of thermostats. Comparisons with the standard clock, the rate of which is determined daily, are made through the agency of a chronograph. The record of the watch is made by means of a tapping key as the second hand reaches the 58th, 60th and 2nd second on the dial at the time selected. These contacts are registered on the chronograph opposite a record upon which each second of the clock is also recorded electrically. By comparing the watches at the same time each day, no other correction, beyond that for the clock rate, is necessary in order to obtain the daily rate of the watch.

As watches are generally adjusted by the maker in either three or five positions, two classes of trial are adopted; Class A for five position adjustment and Class B for three position adjustment.

A short five position trial, Class C, is also provided for those who do not wish to be deprived of the use of their watches for the period of time covered by a Class A trial.

PROGRAMME OF TRIAL—CLASS A

The complete trial comprises Parts I, II, III and IV; namely position test, isochronism test, temperature test and recovery test. The period of time covered by a watch undergoing Class A trial is about 55 days.

—	Period	Temp.	Duration in days	Position and Remarks
Part I. (Position).	1	28°C.	3	Vertical, pendant up.
	2	"	3	Vertical, pendant 90° to the right.
	3	"	3	Vertical, pendant 90° to the left.
	4	"	3	Horizontal, dial up.
	5	"	3	Horizontal, dial down.
	6	"	3	Horizontal, dial down.
	7	"	3	Horizontal, dial up.
	8	"	3	Vertical, pendant 90° to the left.
	9	"	3	Vertical, pendant 90° to the right.
	10	"	3	Vertical, pendant up.
Part II. (Isochronism).	11	28°C.	2	Vertical, pendant up. Comparisons with clock made every three hours until watch runs down.
Part III. (Temperature).		5°C.	1	Horizontal, dial up, Intermediate day (watch not rated).
	12	"	5	Horizontal, dial up.
		20°C.	1	Horizontal, dial up, Intermediate day (watch not rated).
	13	"	5	Horizontal, dial up.
		35°C.	1	Horizontal, dial up, Intermediate day (watch not rated).
	14	"	5	Horizontal, dial up.
Part IV. (Recovery).		28°C.	1	Vertical, pendant up, Intermediate day (watch not rated).
	15	"	3	Vertical, pendant up.

Part I (Position Test).—The position test indicates the degree of adjustment attained in the five positions, pendant up, pendant right, pendant left, dial up and dial down. During the rating of the watch in the different positions of adjustment mentioned, the temperature is regulated to about 28° C., this being assumed to be the temperature of a watch in a man's pocket and therefore that at which it will be used.

Owing to the gradual increase or decrease in rate with time, which is often present in a watch, each of the position test intervals is divided into two periods of three days each. These are arranged so that the central days of each of the two three-day periods for any one position occur at the same interval of time before and after the end of the first half of the position test. By this arrangement the mean daily rate in any of the positions, obtained from taking the mean of the rates for the corresponding six days, will give a comparison of the rates in the different positions independent of the progressive change in rate. The actual amount of this progressive change in rate may be obtained from the difference in the mean daily rate of the two three-day intervals during which the watch is in the same position.

Part II (Isochronism Test).—The isochronism adjustment of the watch, or uniformity of rate throughout the day, is tested in this part. Comparisons are made with the standard clock every three hours, the watch being kept in the vertical, pendant up position at a temperature of 28° C. Although the isochronism error for the first 24 hours is the only factor of great importance, it is customary to prolong this test until the watch runs down.

Part III (Temperature Test).—The tests of temperature adjustment of the watch are run at temperatures of 5° , 20° , and 35° C., in the horizontal, dial up position. It will be noticed from the programme of trial, that at all times when the watches are submitted to a change of temperature, they are not rated until 24 hours after exposure to the new temperature.

Part IV (Recovery Test).—The last part of the trial gives the recovery of rate, or difference between the daily rate in the same position (vertical, pendant up) at the beginning and end of the trial.

Tolerances—Class A

The quantities of importance in determining the quality of a watch, and the tolerances allowed are:—

1. *The mean deviation of daily rate.*—The mean daily rate in each of the periods in the position, temperature and recovery tests, Parts I, III and IV, is first computed and the residual for each day from the mean of the period in which it occurs is obtained. The arithmetic mean of these residuals is the mean deviation of daily rate. This quantity shows the constancy of the daily rate of the watch and the mean of the 48 residuals so obtained must not exceed 0.75 seconds.
2. *The mean deviation for change of position.*—The mean daily rate for each of the double periods of six days during which the watch is in any one position is computed for each of the positions and the algebraic mean of these five quantities is then obtained. Each of the position means is then subtracted from this algebraic mean. The arithmetic mean of the five residuals so found is the mean deviation for change of position; it must not be greater than 3.0 seconds.

3. *The maximum change of daily rate for change of position.*—The greatest difference between any two of the five mean daily rates for the different positions, as obtained above, must not be more than 10 seconds.
4. *Variation of rate between the vertical pendant up, horizontal dial up and horizontal dial down positions:*—
 - (a) The difference between the mean daily rates in the vertical pendant up and the horizontal dial up positions, must not exceed 5.0 seconds.
 - (b) The difference between the mean daily rates in the horizontal dial up and the horizontal dial down positions, must not exceed 4.0 seconds.
5. *Progressive change of rate.*—In order to obtain the mean value of the progressive change of rate during the position test, the difference is found between the mean rate for the two periods in which the watch is in the same position, for each of the five positions. These are the periods 1 and 10, 2 and 9, 3 and 8, 4 and 7, and 5 and 6. The algebraic mean of these five differences is taken as the progressive change of rate in 15 days, and the limit allowed for it is 3.0 seconds. The progressive change of rate is positive when the watch runs slower at the end of the 15 day period, and negative when it runs faster.
6. *The recovery of rate.*—This quantity is the difference between the mean daily rate in the pendant up position at the commencement of the test, period 1, and at the end, period 15. It must not exceed 6.0 seconds. The same convention for sign is adopted as in the case of the previous quantity.
7. *The isochronism error.*—This quantity is found by comparing the rate at which the watch is gaining or losing at the end of 12 hours from being wound with the rate when 24 hours have elapsed. Twice the amount gained or lost in the first 12 hours is subtracted from the amount gained or lost in the initial 24 hours; the difference must be within the limit of 3.0 seconds. When it is positive the watch runs at a slower rate in the first 24 hours from winding than it does in the first period of 12 hours, and when negative the watch runs at a faster rate in the first 24 hours than in the first 12 hours.
8. *Criteria of temperature test:*—
 - (a) The difference between the mean daily rate at 5° C. and that at 35° C. is divided by the range in degrees. This quantity shows the degree of success of the adjustment for temperature. It must not exceed 0.20 seconds.
 - (b) From the mean daily rate for each of the three temperature test periods (Part III) the algebraic differences of rate per degree between 5° and 20° and between 5° and 35° are computed. The difference between these two quantities is of main interest to the user of the watch as it is a measure of the degree of temperature compensation. It must be within the limit of 0.30 seconds.
9. *Limit of rate.*—In no case must the mean daily rate in any of the position or temperature test periods exceed 10 seconds.

Marks:—The marks awarded for the performance of a watch which has undergone trial A are computed from the following formula:—

$$\text{Marks} = 30 \left(1 - \frac{a}{0.75} \right) + 30 \left(1 - \frac{b}{3.0} \right) + 30 \left(1 - \frac{c}{0.25} \right) + 10 \left(1 - \frac{d}{6.0} \right)$$

Where a = the observed "mean deviation of daily rate." (Paragraph 1 above.)

b = the observed "mean deviation for change of position." (Paragraph 2 above.)

c = the arithmetic mean of the difference of rate per degree centigrade between 5° and 35° and the amount by which the difference of rate per degree between 5° and 20° differs algebraically from the difference of rate per degree between 5° and 35° C.

d = the recovery of rate. (Paragraph 6 above.)

PROGRAMME OF TRIAL—CLASS B

The trial includes Part I (position test), Part II (temperature test) and Part III (recovery test). In the position test the watch is rated in three positions only—vertical, pendant up, horizontal, dial up, and horizontal, dial down. The period over which the test extends is about 40 days.

—	Period	Temp.	Duration in days	Position and Remarks
Part I. (Position).	1	28°C	3	Vertical, pendant up.
	2	"	3	Horizontal, dial up.
	3	"	3	Horizontal, dial down.
	4	"	3	Horizontal, dial down.
	5	"	3	Horizontal, dial up.
	6	"	3	Vertical, pendant up.
Part II. (Temperature).	7	5°C	1	Horizontal, dial up, Intermediate day (watch not rated).
		"	5	Horizontal, dial up.
	8	20°C	1	Horizontal, dial up, Intermediate day (watch not rated).
		"	5	Horizontal, dial up.
		35°C	1	Horizontal, dial up, Intermediate day (watch not rated).
	9	"	5	Horizontal, dial up.
Part III. (Recovery).	10	28°C	1	Vertical, pendant up, Intermediate day (watch not rated).
		"	3	Vertical, pendant up.

Tolerances—Class B

The quantities mentioned in the following tolerances have been explained when dealing with the Class A trial.

1. The mean deviation of daily rate must not exceed 1.0 seconds.
2. The difference between the mean rates in the vertical pendant up and the horizontal dial up positions must not exceed 6.0 seconds.
3. The difference between the mean rates in the horizontal dial up and the horizontal dial down positions not to exceed 5.0 seconds.

4. *The recovery of rate* (period 10 minus period 1) not to exceed 8.0 seconds.
5. *The difference of rate per degree centigrade between 5° and 35° C.* not to exceed 0.30 seconds.
6. *The difference of rate per degree centigrade between 5° and 20° C.* not to differ algebraically from that between 5° and 35° C. by more than 0.40 seconds.
7. *The mean daily rate of any of the 10 periods* not to exceed 10 seconds.

No marks are awarded in the case of a watch undergoing a Class B trial.

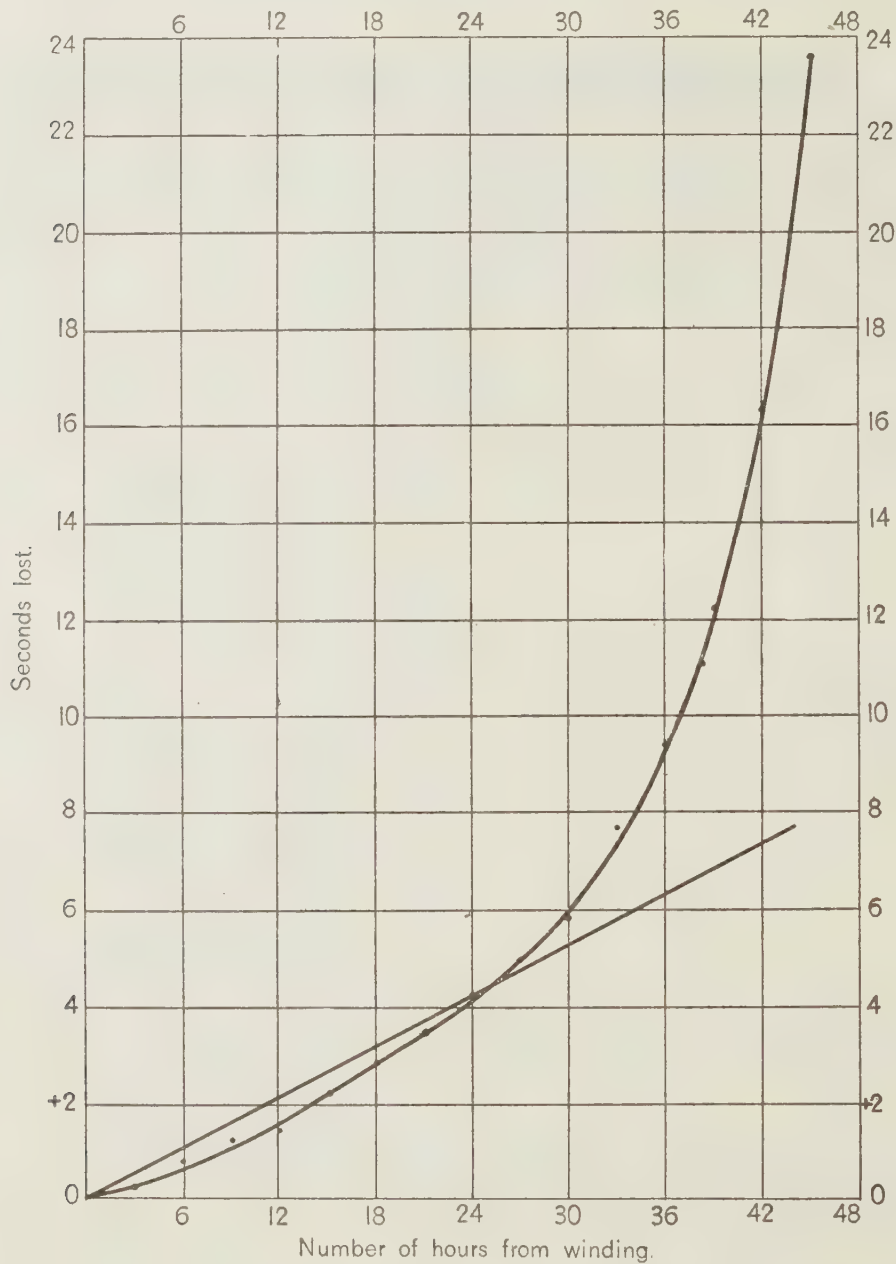


Fig. 1.—Isochronism curve of a watch well within Class A tolerances.

SHORT TRIAL—CLASS C

A watch that will successfully comply with Class A tolerances is necessarily a high grade timepiece in excellent adjustment. Such a watch, if treated with care, should be reliable for surveying, navigation and other work demanding very high accuracy. It is not always convenient, however, for all users to

be deprived of their watches for the two months necessary for a Class A trial. To meet the needs of these and others who do not require such refinements as are necessary in a Class A watch, a shorter trial has been developed at the Surveys Laboratory. The record of the performance of a watch undergoing this trial will denote its suitability for nearly all practical purposes. If railways and many other commercial users submitted their watches for this short trial, a far better knowledge of the performance could be obtained than by merely considering the time-keeping properties over an extended period.

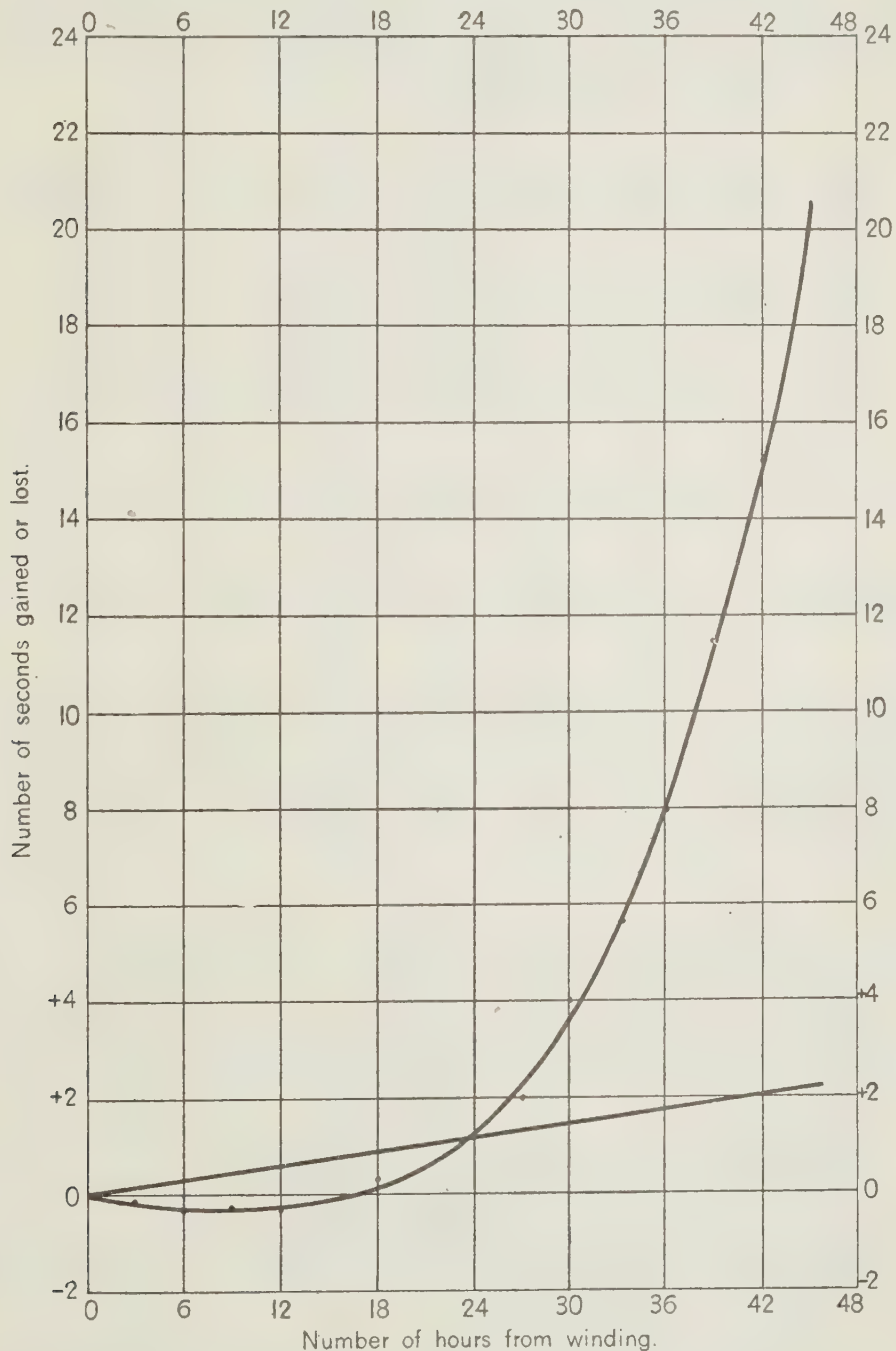


Fig. 2.—Isochronism curve of a watch just complying with Class A tolerances.

For a Class C certificate, the watch is rated for three days only in each of the five positions and at the three temperatures of the previous tests. An isochronism test is also made similar to that in the Class A trial. Thus the time occupied is only about four weeks. The tolerances adopted are necessarily more generous than in the longer tests, but a watch successfully passing the short trial can be expected to give good service.

In all classes of trial, summaries are prepared showing the rate of the watch in the different positions and the values of the various quantities for which tolerances are allowed. Certificates are also issued in the case of watches which successfully pass the trial.

GRAPHS

The results of the isochronism and temperature tests for each watch are plotted graphically, so that the degree of adjustment obtained in each case may be easily seen. A study of these graphs is of interest.

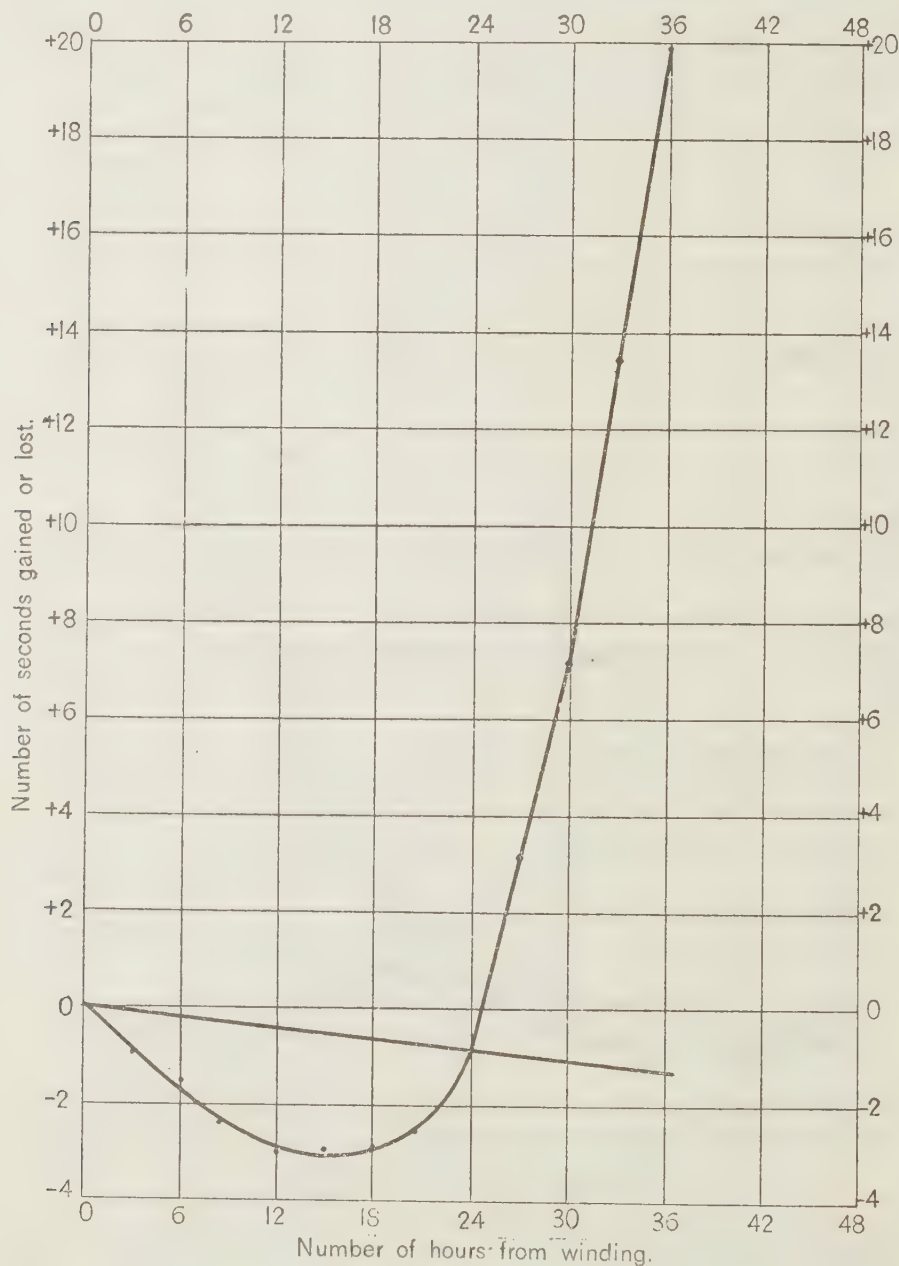


Fig. 3.—Isochronism curve of a watch failing under Class A tolerances.

Isochronism Curves.—The isochronism curve for a watch complying with Class A tolerances is reproduced in Fig. 1. The straight line in this, and the following isochronism curves indicates what the rate of the watch would be if it were perfectly adjusted for isochronism. It will be noticed that the isochronism error is very small for the first 24 hours, after which the

error becomes proportionately much larger. This feature illustrates the necessity for winding at regular periods of not greater than twenty-four hours. In Fig. 2 is shown the graph of a watch just within the Class A tolerances,

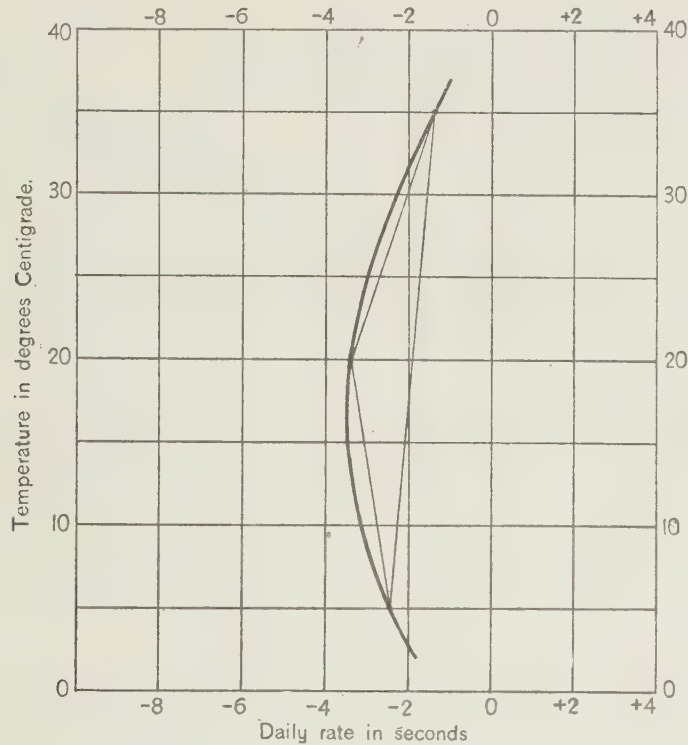


Fig. 4.—Temperature curve showing good adjustment of a well compensated watch.

while in Fig. 3 is reproduced the curve of a watch poorly adjusted for isochronism. The vertical ordinates between the curve and the straight line drawn through the zero and 24 hour points in each case are a measure of the isochronism error, and at once show clearly the variation in value of this error at different periods of the test.

Temperature Adjustment.—It has been previously indicated in defining temperature compensation, that usually a good watch, when well adjusted, will have very nearly the same rate at the two extreme temperatures of adjustment, with the intermediate change of rate as small as possible. The graph showing the rate of such a watch at different temperatures is shown in Fig. 4. The daily rate at 5° C. being —2.4 seconds, at 35°C.—1.4 seconds, while at 20° C. it is—3.4 seconds. This watch may be considered as well adjusted for temperature, the temperature of compensation being about 17°C. As a contrast Fig. 5 shows a poorly adjusted watch when the change of rate per degree is large and, moreover, changing from the highest to lowest temperature of test would alter the daily rate by 20 seconds. In this case it will be noticed that there is no temperature of compensation within the limits of the test. For the purpose of comparison the limits allowed for a watch having zero rate at 5° C., and just passing Class A trial are shown by the full line of Fig. 6. The dotted lines show the limits for the same watch, applying Class B tolerances.

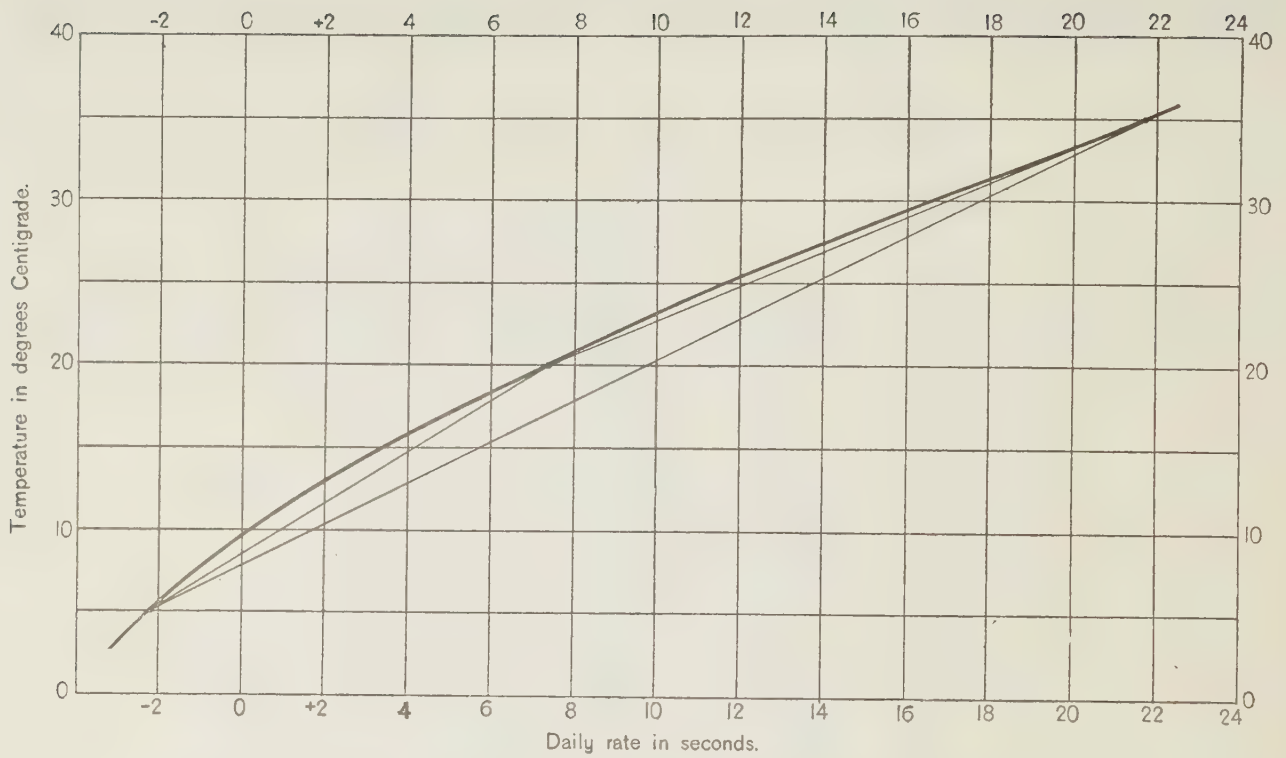


Fig. 5.—Temperature curve of a poorly adjusted watch.

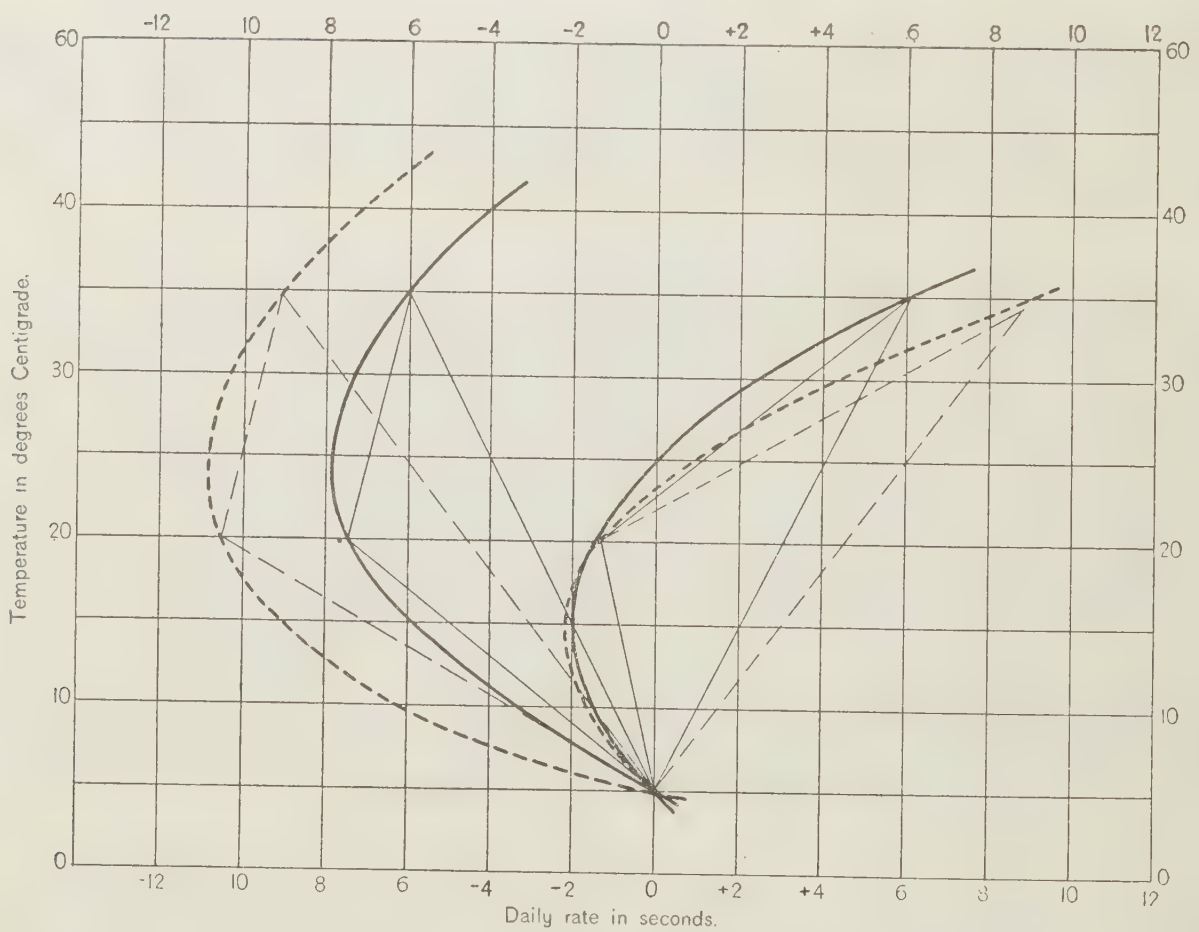


Fig. 6.—Curves showing limits of variation of rate with temperature.
 Full lines.....Class A tolerances.
 Dotted lines.....Class B tolerances.

CONCLUSION

It is frequently stated that a certain watch gains or loses only one or two seconds in a month or over some other long interval of time. While a variation of this order would seem to indicate a watch of excellent quality, the various points discussed in this pamphlet will serve to show how deceiving such a statement may be. The adjustment of a watch is at best a compromise, it being impossible to eliminate all variations in the rate with change of conditions. Owing to the interdependency of the various adjustments and to other factors, all that the adjuster can do is to strive to reduce the various errors within certain limits. Although a watch may show no error after the lapse of several days, it may yet have been very far from accurate at times during the interval. Even within twenty-four hours a watch, similar to that for which the isochronism curve is shown in Fig. 3, may be in error by a considerable amount and yet be apparently a very accurate time-keeper when considering only the beginning and end of this period.

When little or no care is exercised as to the position or temperature at which a watch is kept, accurate time-keeping is practically impossible. It is hardly necessary to remark that such a delicate mechanism as that of a watch should be protected against dust, jars, sudden change of temperature and other ill treatment. The foregoing account of the method of test and the actual performance of the watch obtained from the certificate will indicate in particular, the means by which the best results may be obtained in actual use. In the first place, a study of the temperature adjustment curves will illustrate the necessity of allowing the watch to remain at as uniform a temperature as possible. The isochronism curves show how important it is to wind the watch at regular intervals. At the same time the results of the position tests emphasize the need for keeping the watch at night in the same position as that occupied during the day, or at least in a position that will not introduce a large change of rate.

It is possible for any one to obtain a general knowledge of the time-keeping properties of a watch by comparing it at least once a day with some reliable standard of time. A daily comparison, if carried over a sufficiently long period, will afford valuable information as to the effect of care exercised regarding regular winding and exposure to temperature and position changes. It should also indicate when a watch needs cleaning and adjusting. When an absolutely reliable test is desired, the watch should be submitted to a regular trial by some central bureau as outlined in this bulletin. In this case a certificate would be furnished showing the various characteristics mentioned.

The establishment of this section of the Surveys Laboratory has enabled government surveyors to be supplied with time-pieces of assured quality, necessary for the accuracy demanded in their work. At the same time, it is recognized that there are many others to whom the possession of a reliable watch is an absolute necessity. The facilities offered by this laboratory therefore, afford advantages to interested parties who would otherwise be under the necessity of having their watches tested at some foreign bureau.

CONCLUSION

**BULLETINS ISSUED
BY THE LABORATORY OF THE DOMINION LANDS SURVEYS
DEPARTMENT OF THE INTERIOR**

41. Tests of Small Telescopes at the Laboratory of the Dominion Land Surveys.
42. The Testing of Aneroid Barometers at the Laboratory of the Dominion Lands Surveys.
43. Tests of Timepieces at the Laboratory of the Dominion Lands Surveys.
44. Standardization of Measures of Length at the Laboratory of the Dominion Lands Surveys.
45. Testing of Thermometers at the Laboratory of the Dominion Lands Surveys.

